# Study of Correlations Between SCIAMACHY, MODIS, and CERES Measurements For CLARREO

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**May, 2011**

**Objective:** evaluate the feasibility of using CLARREO solar benchmark for fingerprinting climate changes.

To use the atmospheric/cloud/surface properties from MODIS to test and validate the fingerprinting results from SCIAM data, **we need to know**

- Are the measurements from the different platforms correlated?
- If yes, how well are they correlated?
- How much will the sampling difference and possible instrument degradation affect the correlation, and hence the fingerprinting?

**Then, we can determine**

- ✓ Are the fingerprinting and its validation based on observations from multi-platforms feasible?
- ✓ If yes, what's the expected accuracy limit of fingerprinting detection?

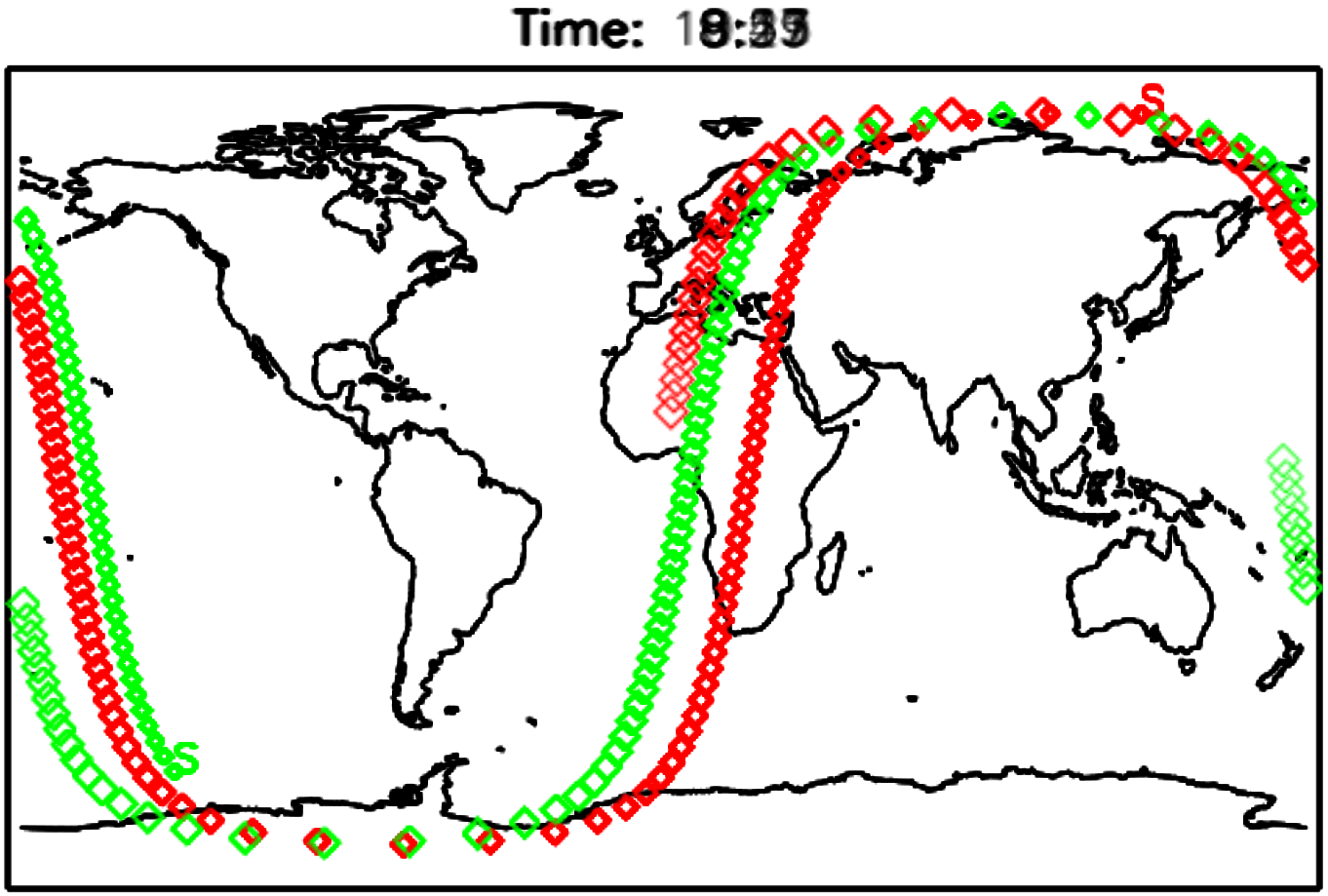
## Table 1. The Data Sets Used in This Study

| Sensor | Measurement | Spectral range | Platform |
|---|---|---|---|
| SCIAM | Spectral radiance solar irradiance | 0.25 – 1.75 µm (Δλ: 0.24-1 nm) | Envisat |
| MODIS | Spectral radiance | Channels 1 and 2 (645 nm; 858nm) | Terra |
| CERES | Broadband radiance | 0.3 – 5.0 µm | Terra |

**Envisat and Terra have similar sun-synchronous orbit:**

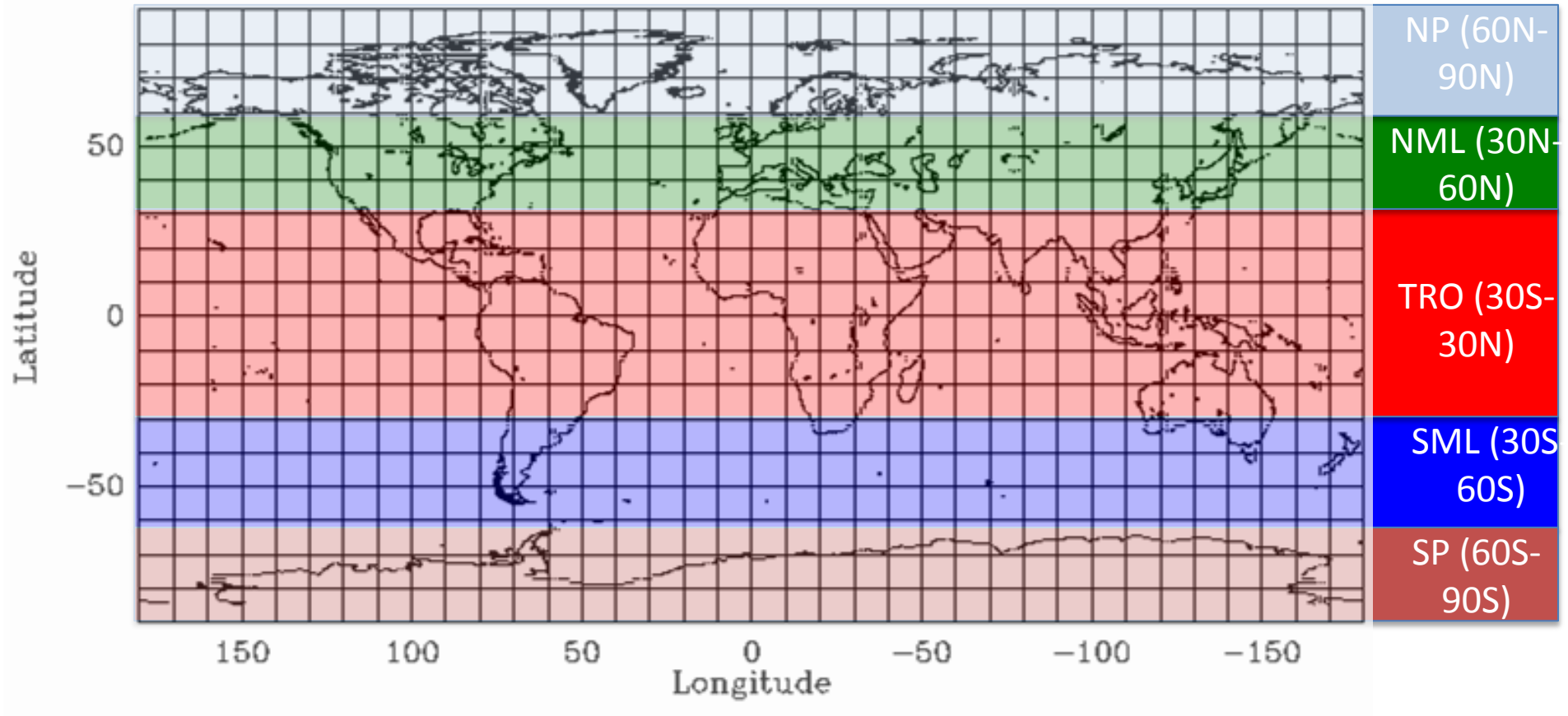
| Satellite | Altitude | Inclination | Period | Equator crossing |
|---|---|---|---|---|
| Envisat | 799.8 km | 98.6° | 100.6 min | 10:00 LST |
| Terra | 705 km | 98.2° | 98.8 min | 10:30 LST |

## MODIS/CERES (Terra) and SCIAMACHY (Envisat) ground tracks
## 8:30 – 10:30, 09-30-2011

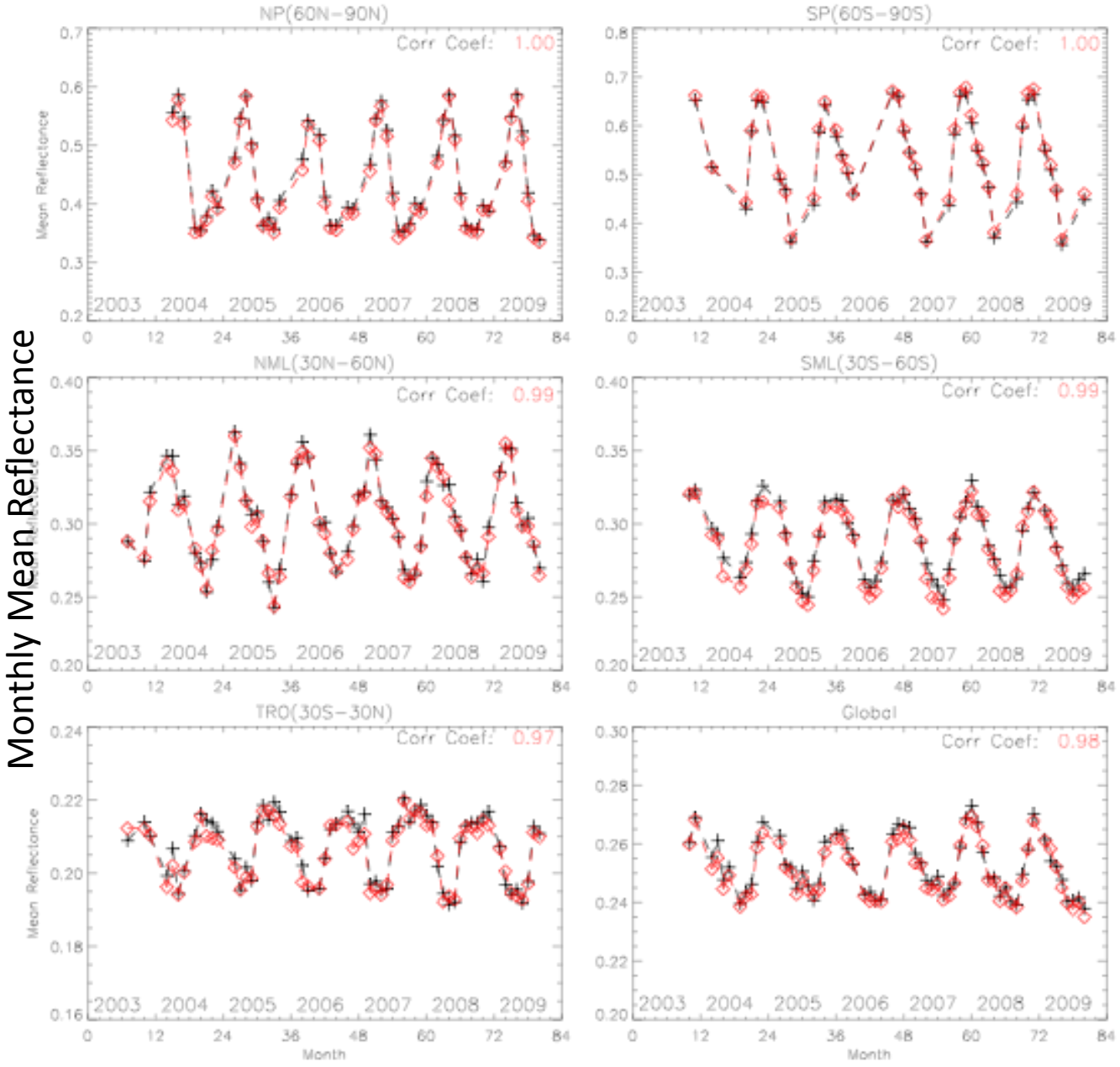



The average time difference of overpass between Envisat and Terra is about 30 min. This **doesn't** mean that the measurements from them are nearly co-incident or co-located.

# Five latitude regions




Monthly averages are done in the 5 large latitude regions and globe.

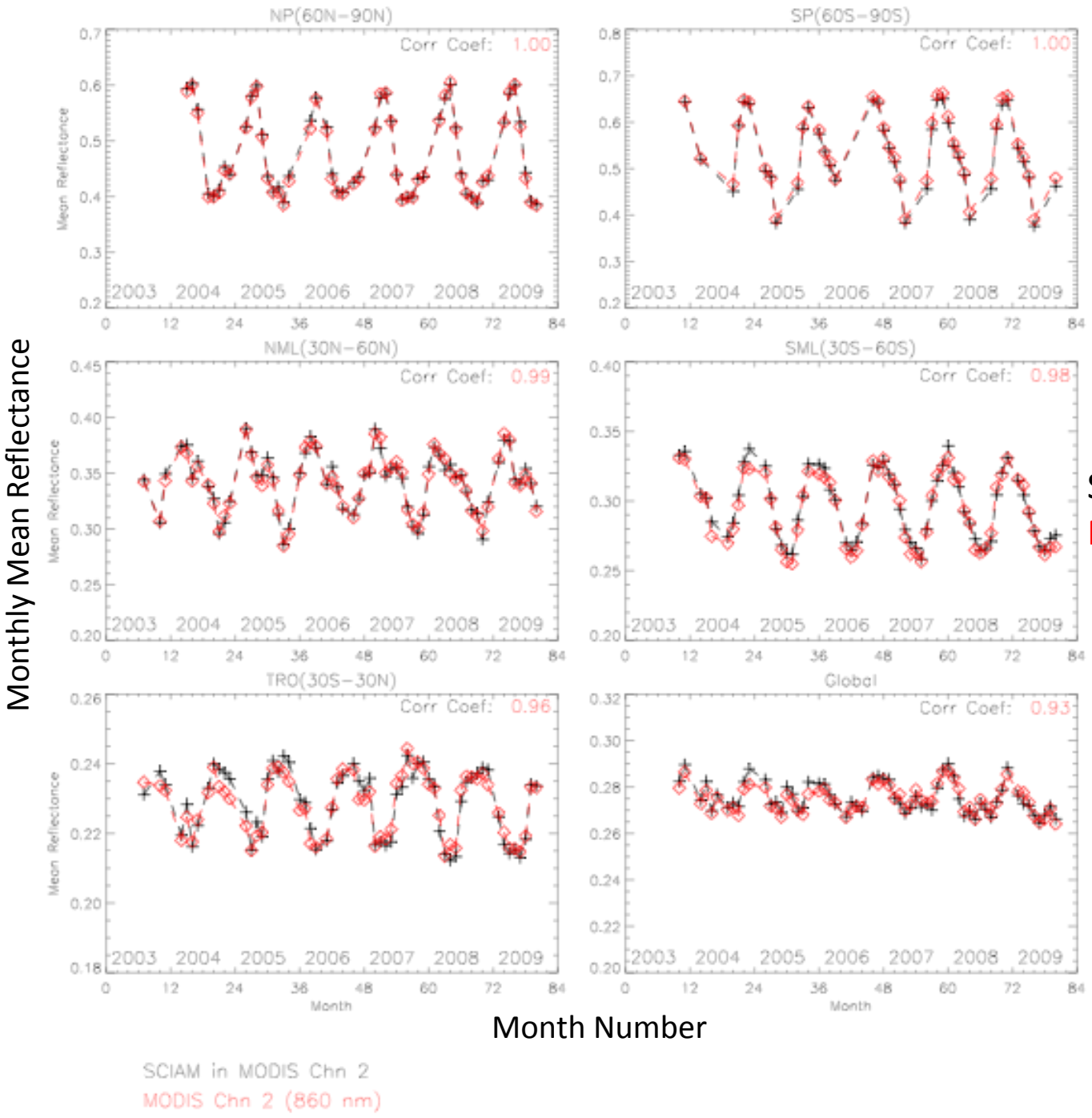



SCIAM in MODIS Ch1

MODIS Ch1 (640 nm)

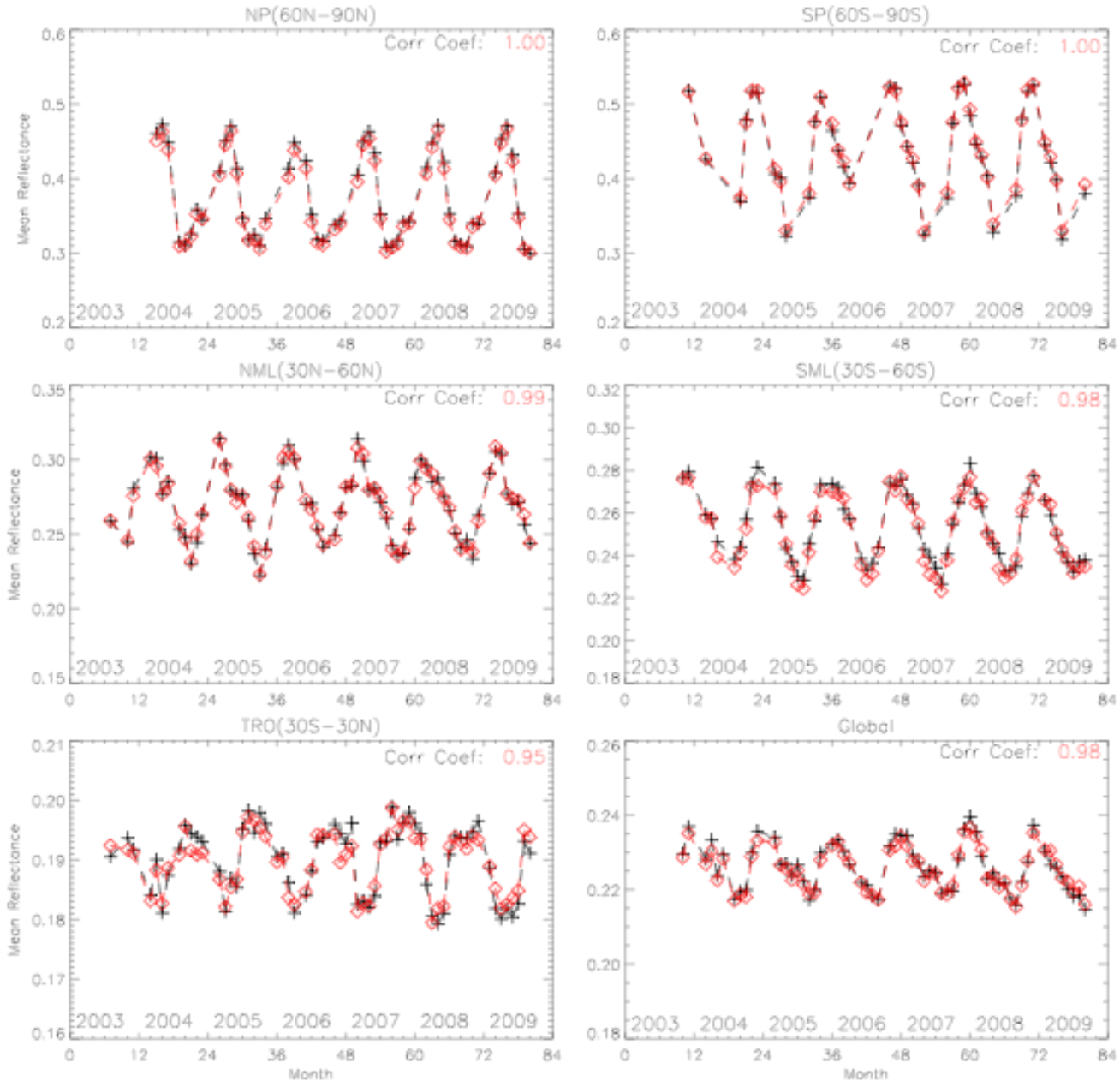
**When averaged to large domains, the two measurements are almost the same though they are not co-located at all!**

**Comparison of monthly mean *nadir* reflectance (10°) between SCIAM and MODIS (Ch1) in 5 latitude regions and globe.**




Same as above, but for MODIS Ch2.

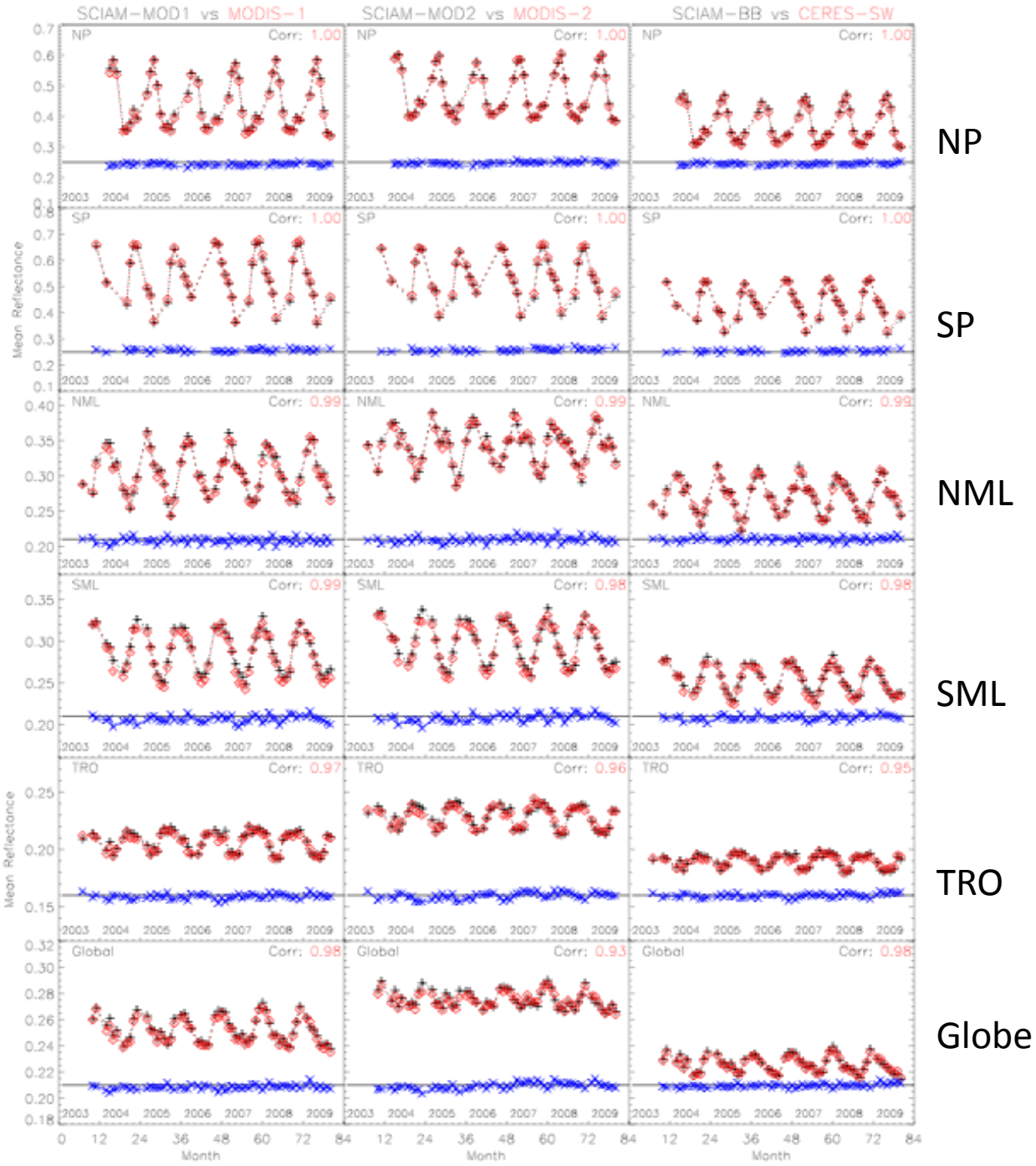
SCIAM in MODIS Ch2
MODIS Ch2 (860 nm)




Same as above, but for broadband shortwave.

SCIAM broadband
CERES SW Ref (nadir)

$$r = \frac{Rad_{\lambda 1-\lambda 2} \cdot \pi D^2}{1365 \cdot \cos(\theta)}$$




Monthly Mean Reflectance

NP

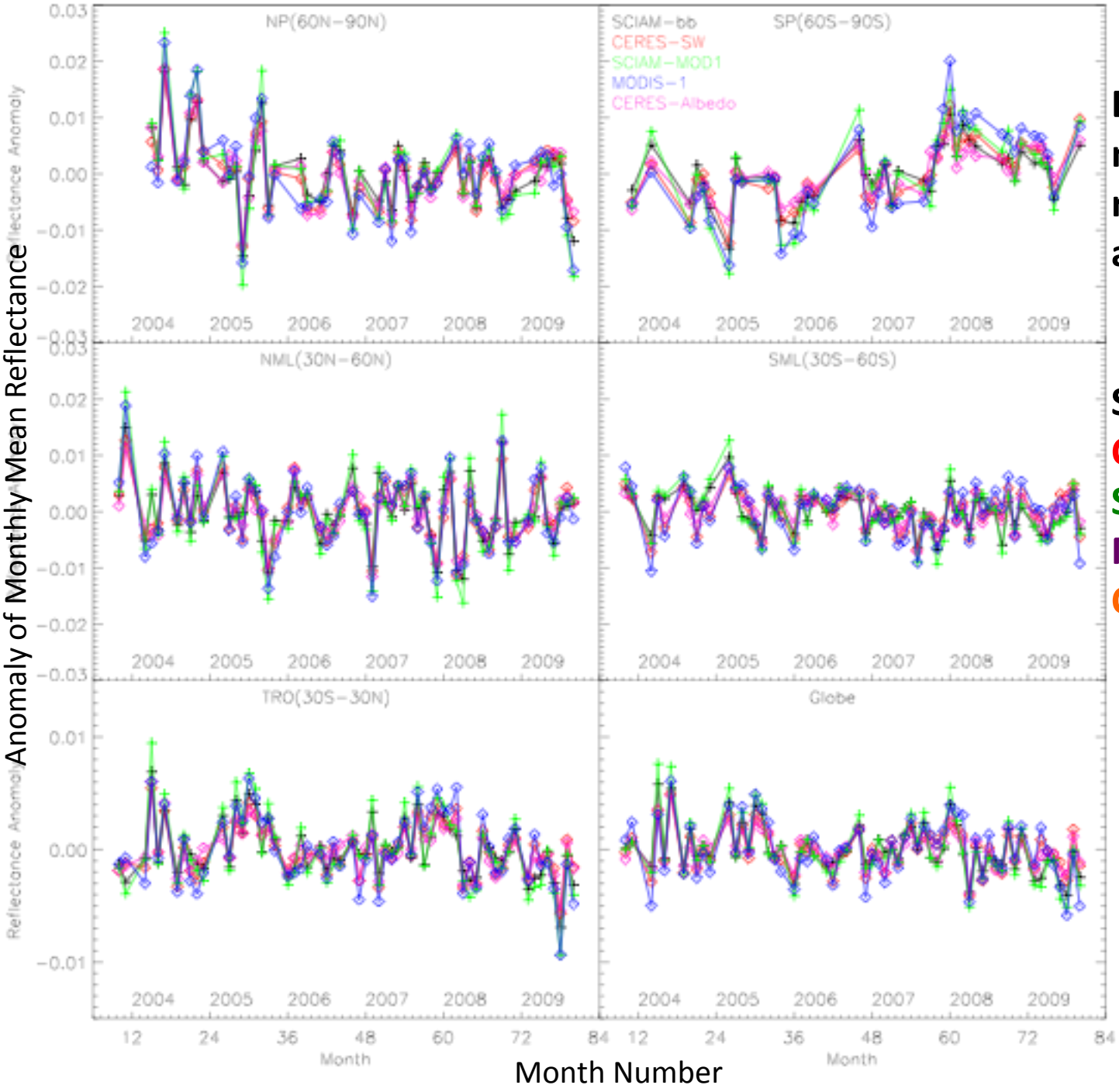
SP

NML

SML

TRO

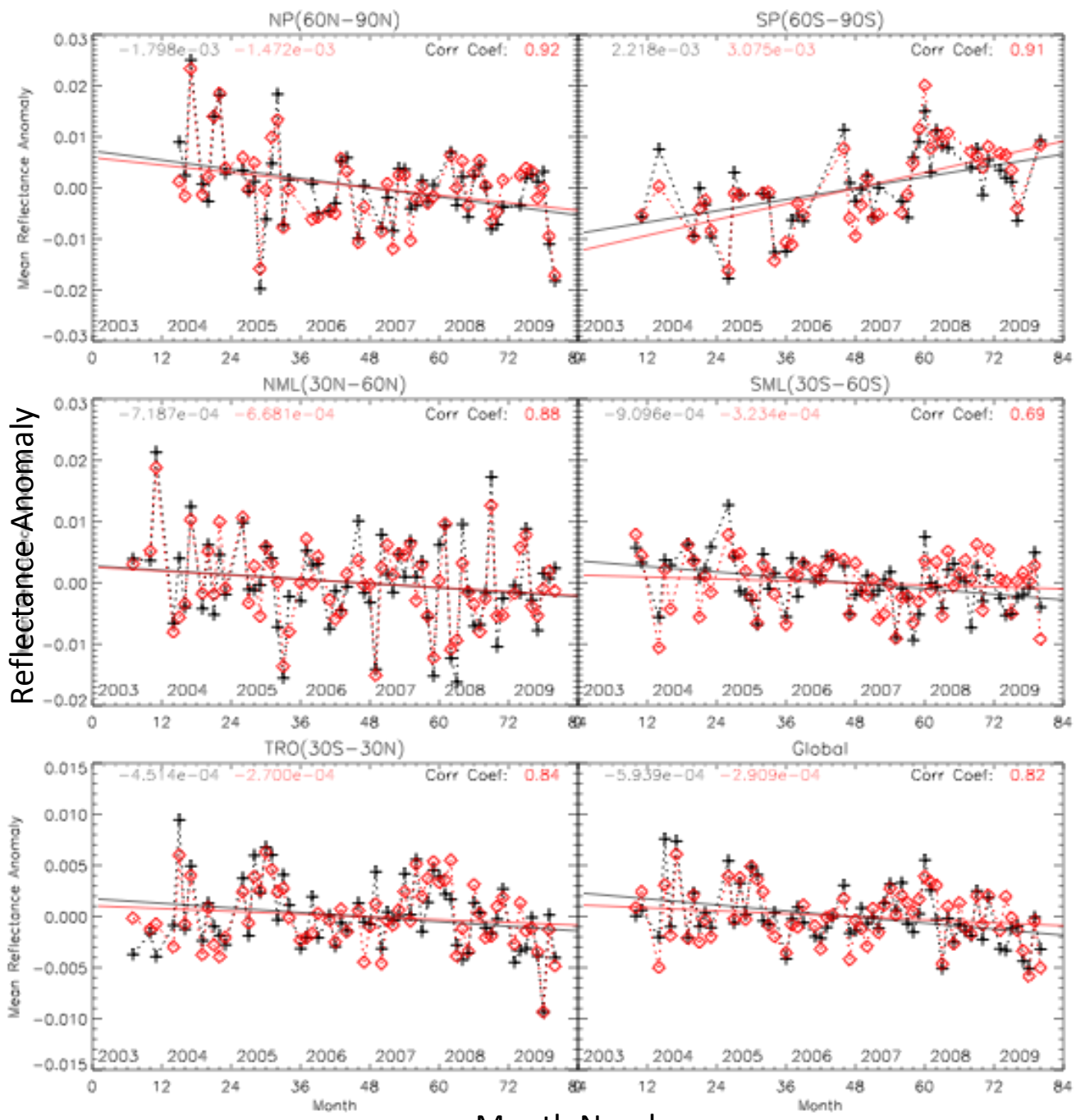
Globe




**Deseaonalized monthly mean reflectance/albedo anomalies.**

**SCIAM-bb**
**CERES-SW**
**SCIAM-MOD1**
**MODIS Ch1**
**CERES albedo**

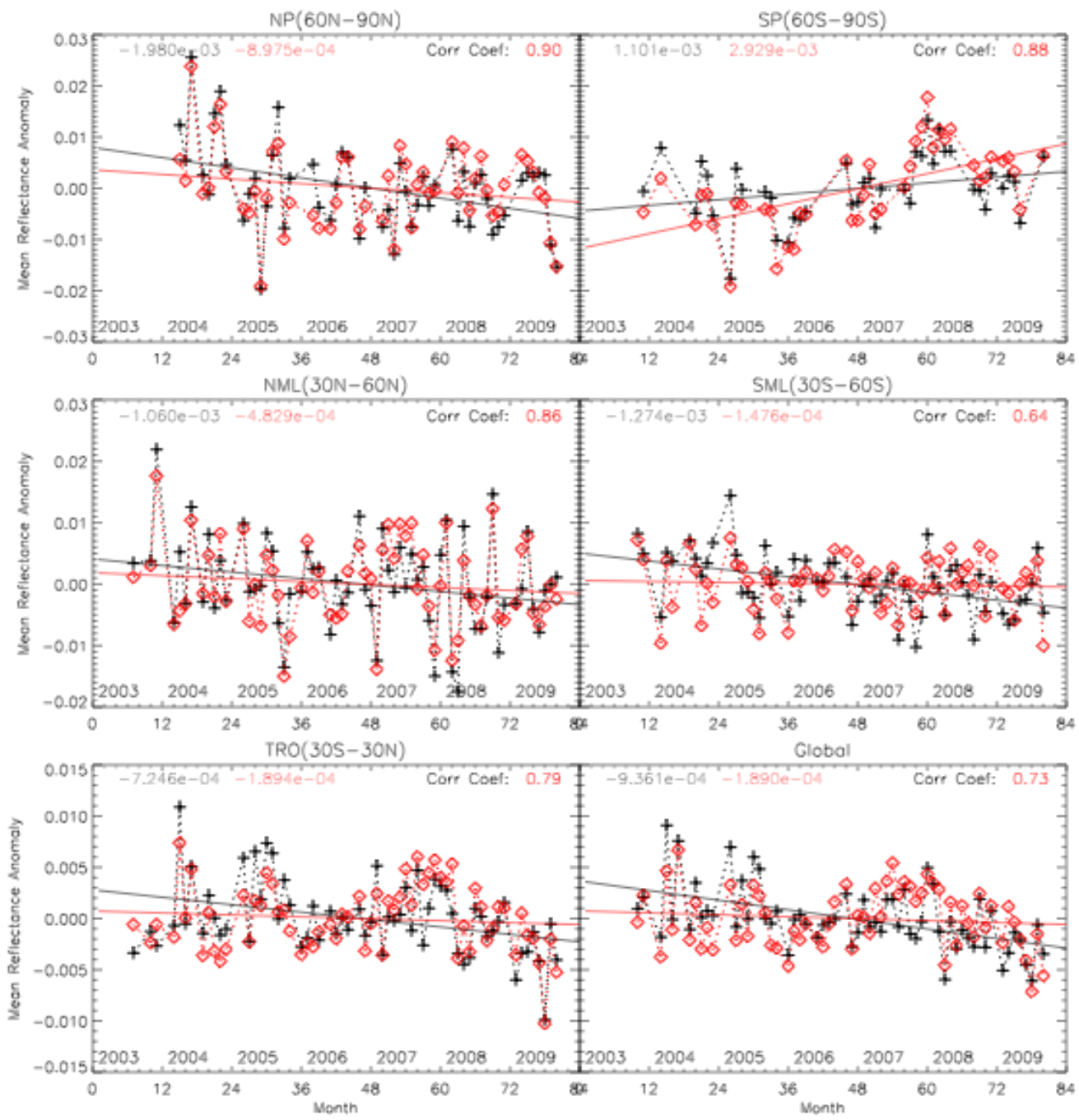
**The anomalies are similar and well correlated too!**




SCIAM-MOD1

MODIS Ch1

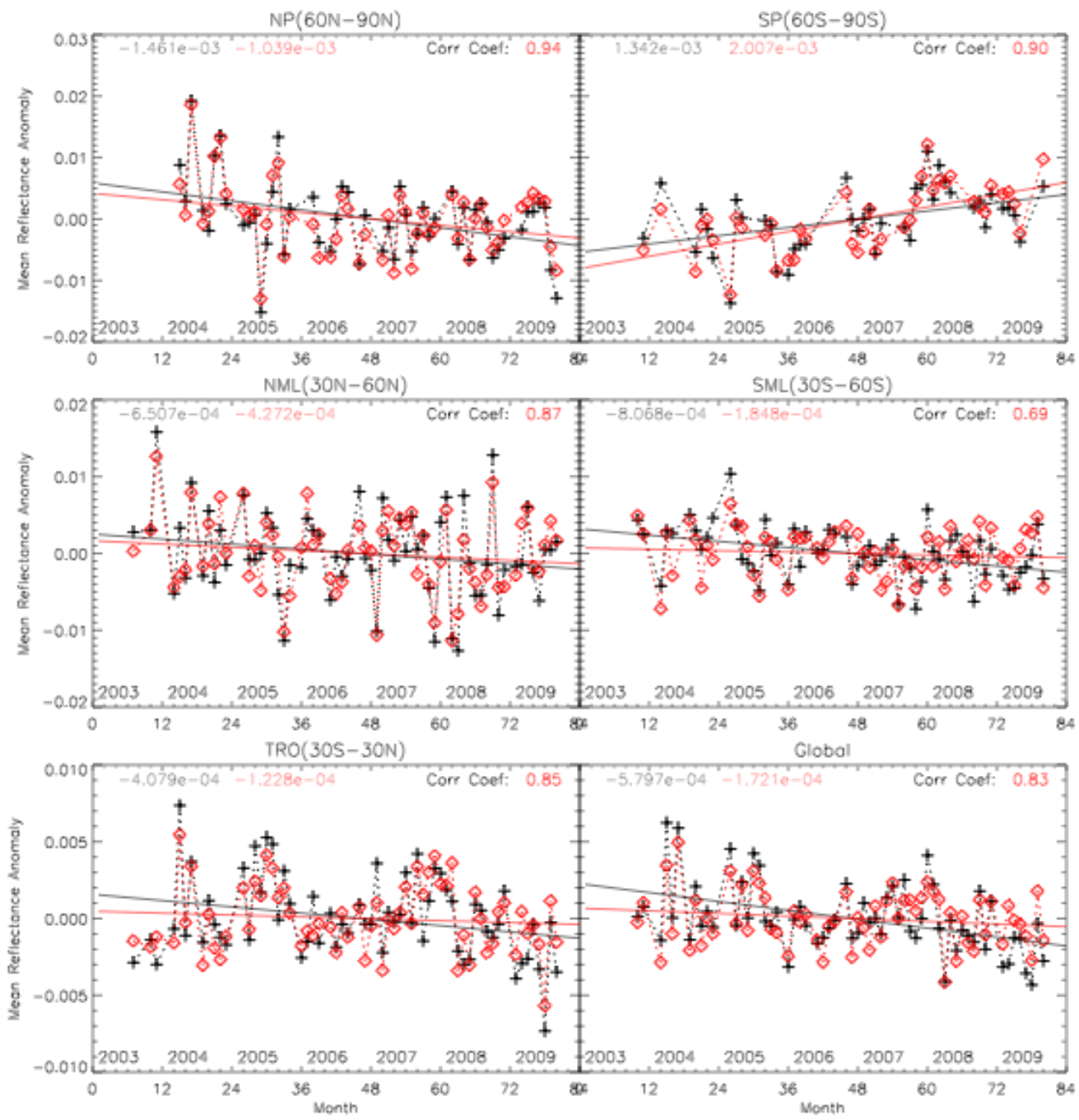
| Region | Slope (decade$^{-1}$) |
|---|---|
| NP | -0.0180 ±0.0128 |
| | -0.0147 ±0.0125 |
| SP | 0.0222 ±0.0126 |
| | 0.0307 ±0.0124 |
| NML | -0.0072 ±0.0109 |
| | 0.0067 ±0.0096 |
| SML | -0.0091 ±0.0061 |
| | -0.0032 ±0.0067 |
| TRO | -0.0045 ±0.0048 |
| | -0.0027 ±0.0045 |
| Glb | -0.0059 ±0.0039 |
| | -0.0029 ±0.0039 |




SCIAM-MOD2

MODIS Ch2

| Region | Slope (decade$^{-1}$) |
|---|---|
| NP | -0.0198 ±0.0133 |
| | -0.0090 ±0.0130 |
| SP | 0.0110 ±0.0119 |
| | 0.0293 ±0.0126 |
| NML | -0.0106 ±0.0108 |
| | 0.0048 ±0.0100 |
| SML | -0.0127 ±0.0067 |
| | -0.0015 ±0.0066 |
| TRO | -0.0072 ±0.0048 |
| | -0.0019 ±0.0048 |
| Glb | -0.0094 ±0.0040 |
| | -0.0019 ±0.0044 |




SCIAM Broadband
CERES Shortwave

| Region | Slope (decade$^{-1}$) |
|---|---|
| NP | -0.0146 ±0.0098 |
| | -0.0104 ±0.0094 |
| SP | 0.0134 ±0.0091 |
| | 0.0201 ±0.0082 |
| NML | -0.0065 ±0.0083 |
| | -0.0043 ±0.0074 |
| SML | -0.0081 ±0.0048 |
| | -0.0018 ±0.0050 |
| TRO | -0.0041 ±0.0037 |
| | -0.0012 ±0.0032 |
| Glb | -0.0058 ±0.0030 |
| | -0.0017 ±0.0027 |

CERES SW Ref (nadir)

# 1σ of Monthly Mean Reflectance Anomaly in 5 Regions From Different Sensors

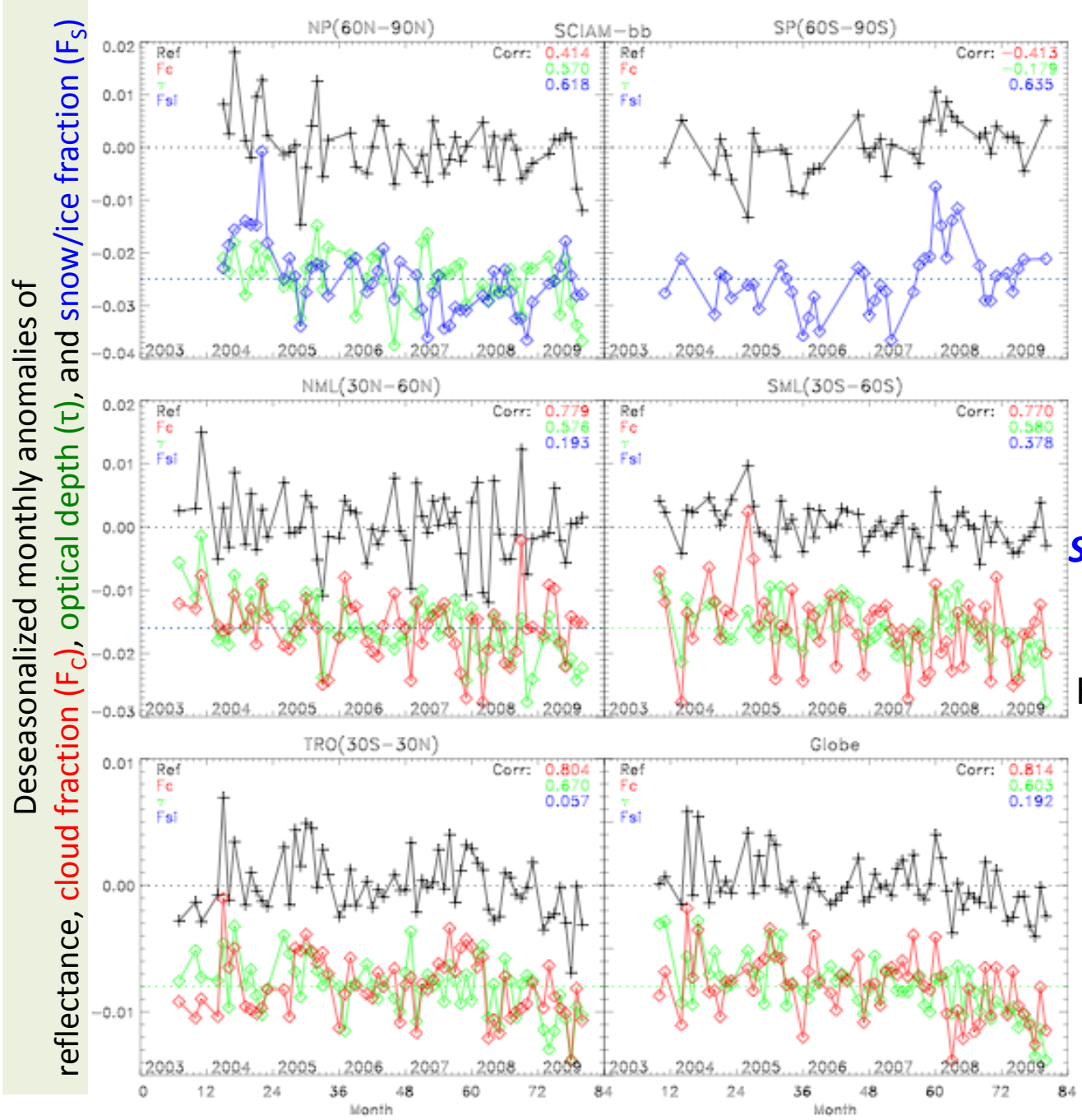
| | SCIAM (bb) | CERES | MOD1 | SCIA in MOD1 | MOD2 | SCIA in MOD2 |
|---|---|---|---|---|---|---|
| NP | 0.00585 | 0.00573 | 0.00766 | 0.00801 | 0.00769 | 0.00838 |
| SP | 0.00487 | 0.00524 | 0.00795 | 0.00726 | 0.00787 | 0.00622 |
| NML | 0.00542 | 0.00503 | 0.00654 | 0.00743 | 0.00678 | 0.00748 |
| SML | 0.00314 | 0.00322 | 0.00435 | 0.00423 | 0.00425 | 0.00477 |
| TRO | 0.00245 | 0.00219 | 0.00310 | 0.00336 | 0.00326 | 0.00349 |
| Globe | 0.00205 | 0.00180 | 0.00261 | 0.00272 | 0.00290 | 0.00305 |

Largest

Smallest

All show largest σ in NP and decreasing in order from NP, SP, NML, SML, TRO to Globe.

- Consistent between measurements from the two platforms in a same band.




Correlations of
***reflectance variation***
with
***cloud fraction ($F_C$)***,
***optical depth (τ)***,
***Snow/sea ice fraction ($F_S$)***

(Shown only parameters having correlation higher than 0.5)

| Region | Para | SCIM-bb | CERES | SCIM-MOD1 | SCIM-MOD2 | CERES-Albedo |
|---|---|---|---|---|---|---|
| NP | $F_c$ | 0.414 | 0.352 | 0.380 | 0.341 | 0.447 |
| | $\tau$ | 0.570 | 0.516 | 0.557 | 0.539 | 0.541 |
| | $F_{SI}$ | 0.618 | 0.631 | 0.602 | 0.666 | 0.624 |
| SP | $F_c$ | -0.413 | -0.486 | -0.393 | -0.423 | -0.358 |
| | $\tau$ | -0.179 | -0.216 | -0.186 | -0.202 | -0.168 |
| | $F_{SI}$ | 0.635 | 0.690 | 0.623 | 0.638 | 0.659 |
| NML | $F_c$ | 0.779 | 0.824 | 0.779 | 0.758 | 0.846 |
| | $\tau$ | 0.576 | 0.591 | 0.573 | 0.604 | 0.551 |
| | $F_{SI}$ | 0.193 | 0.089 | 0.241 | 0.200 | 0.210 |
| SML | $F_c$ | 0.770 | 0.772 | 0.776 | 0.766 | 0.859 |
| | $\tau$ | 0.580 | 0.537 | 0.592 | 0.596 | 0.589 |
| | $F_{SI}$ | 0.378 | 0.158 | 0.390 | 0.393 | 0.254 |
| TRO | $F_c$ | 0.804 | 0.893 | 0.817 | 0.791 | 0.919 |
| | $\tau$ | 0.670 | 0.615 | 0.659 | 0.713 | 0.663 |
| | $F_{SI}$ | 0.057 | -0.011 | 0.056 | -0.009 | -0.007 |
| Globe | $F_c$ | 0.814 | 0.797 | 0.821 | 0.804 | 0.846 |
| | $\tau$ | 0.603 | 0.536 | 0.576 | 0.665 | 0.537 |
| | $F_{SI}$ | 0.192 | 0.191 | 0.198 | 0.192 | 0.245 |

Correlation coefficients of anomalies between the reflectance/albedo and the three parameters ($F_C$ – cloud fraction, τ - cloud optical depth, and $F_S$ – snow and sea ice fraction).

# Summary

1) When averaged over large spatial regions, the monthly mean reflectances in a common spectral band from two independent space platforms (Terra and Envisat) are nearly identical and highly correlated, though their instantaneous measurements are not co-located and thus not comparable.

2) The time series of reflectance anomalies from SCIAM, MODIS and CERES are similar and are well correlated with each other; they are also correlated with the variations of the atmospheric/surface properties, especially cloud fraction, optical depth, and snow/ice coverage.

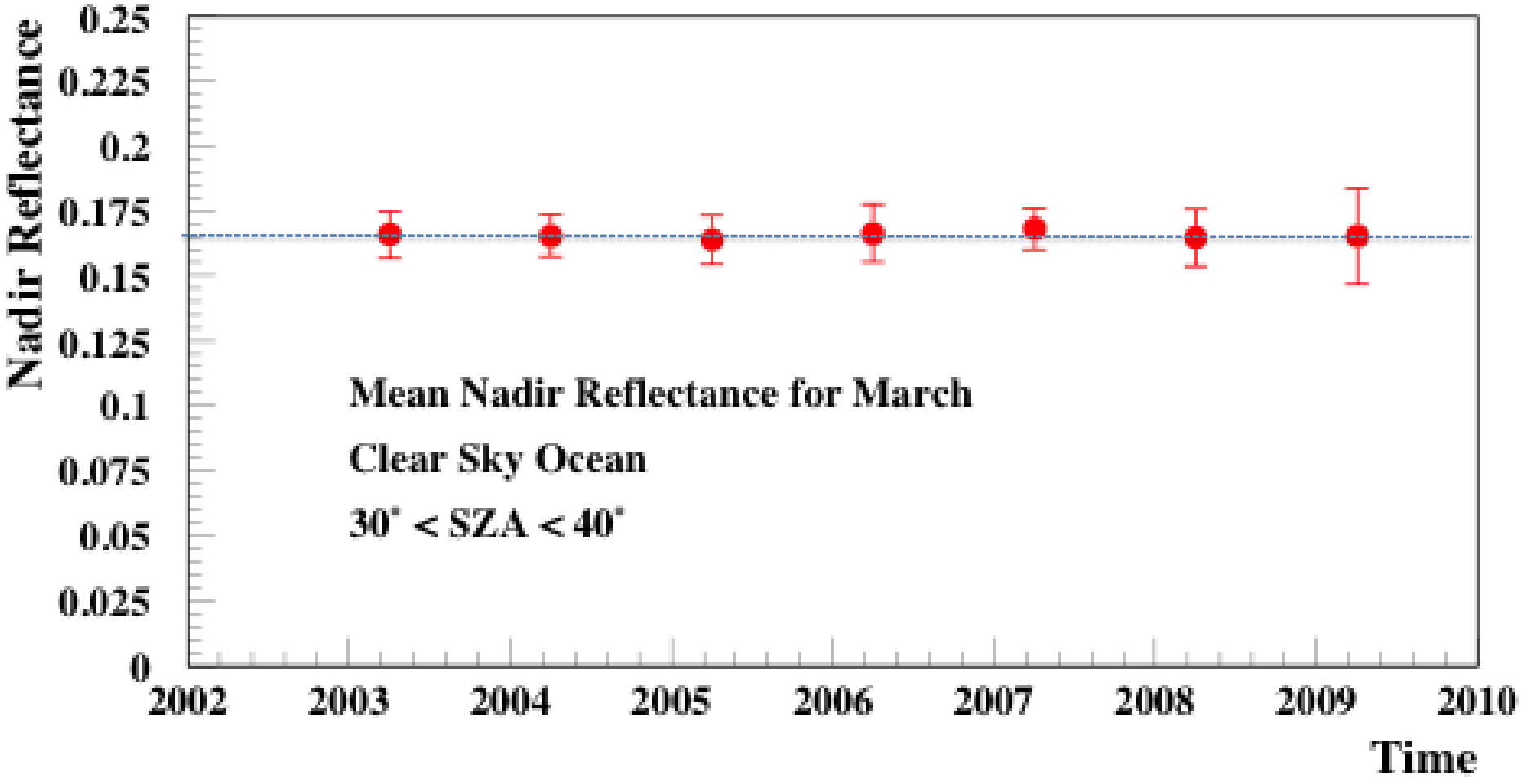
3) Compared with the natural variability, the slope (trend) of mean reflectance change in large climate regions is small; the relative difference in slope from different data sets could be significant due to different instrument degradations.

## 4) The results have implications for CLARREO:

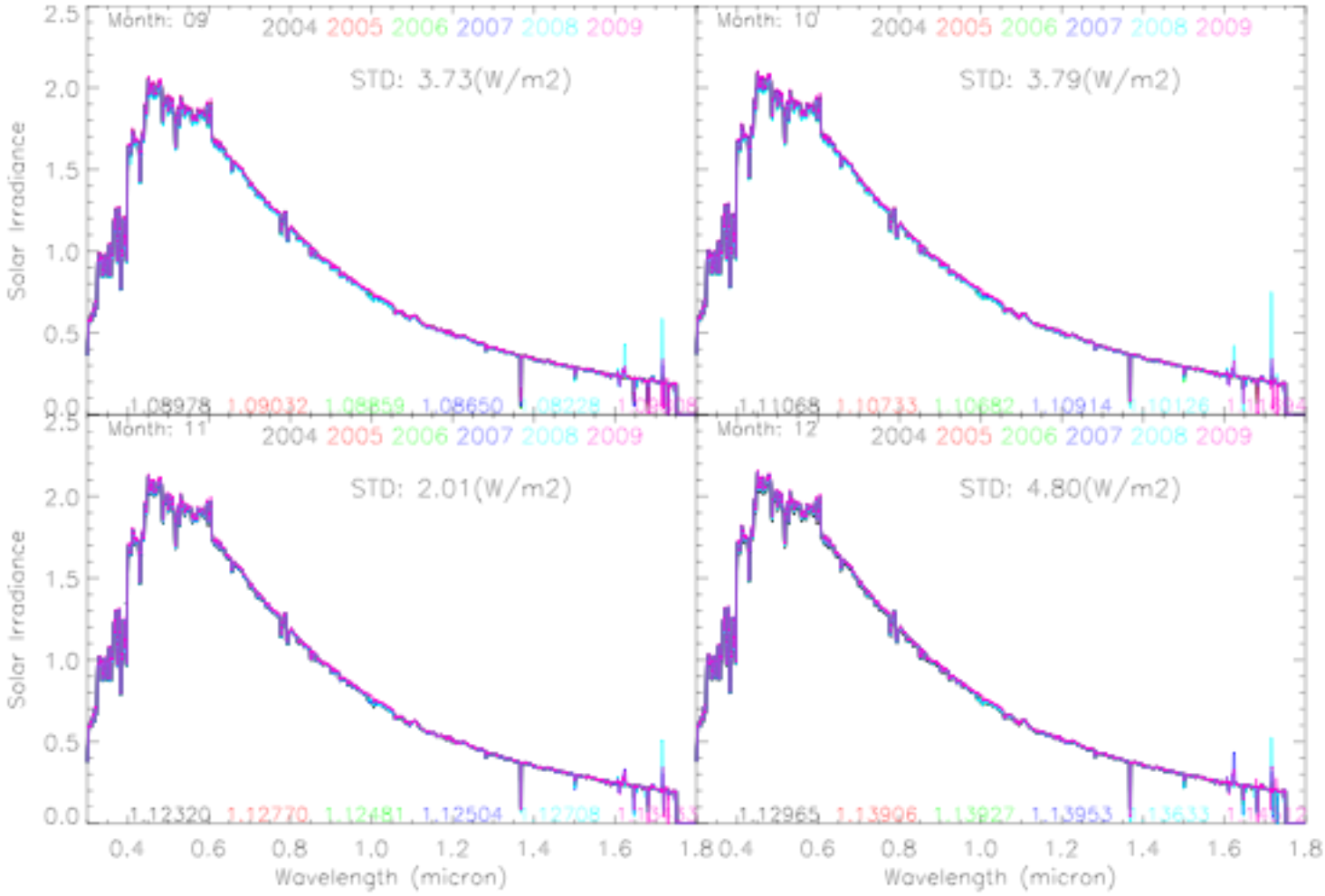
- **The combined data of SCIAM/MODIS/CERES could be used to test the solar fingerprinting approach for CLARREO. However, the inconsistency of stability between different instruments seems too large to have a reliable long-term climate change detection.**
- **The nadir sampling strategy of CLARREO is appropriate and sufficient for the solar benchmarking and fingerprinting.**
- **Reliable solar fingerprinting of climate changes requires accurate and consistent reflectance spectrum.**

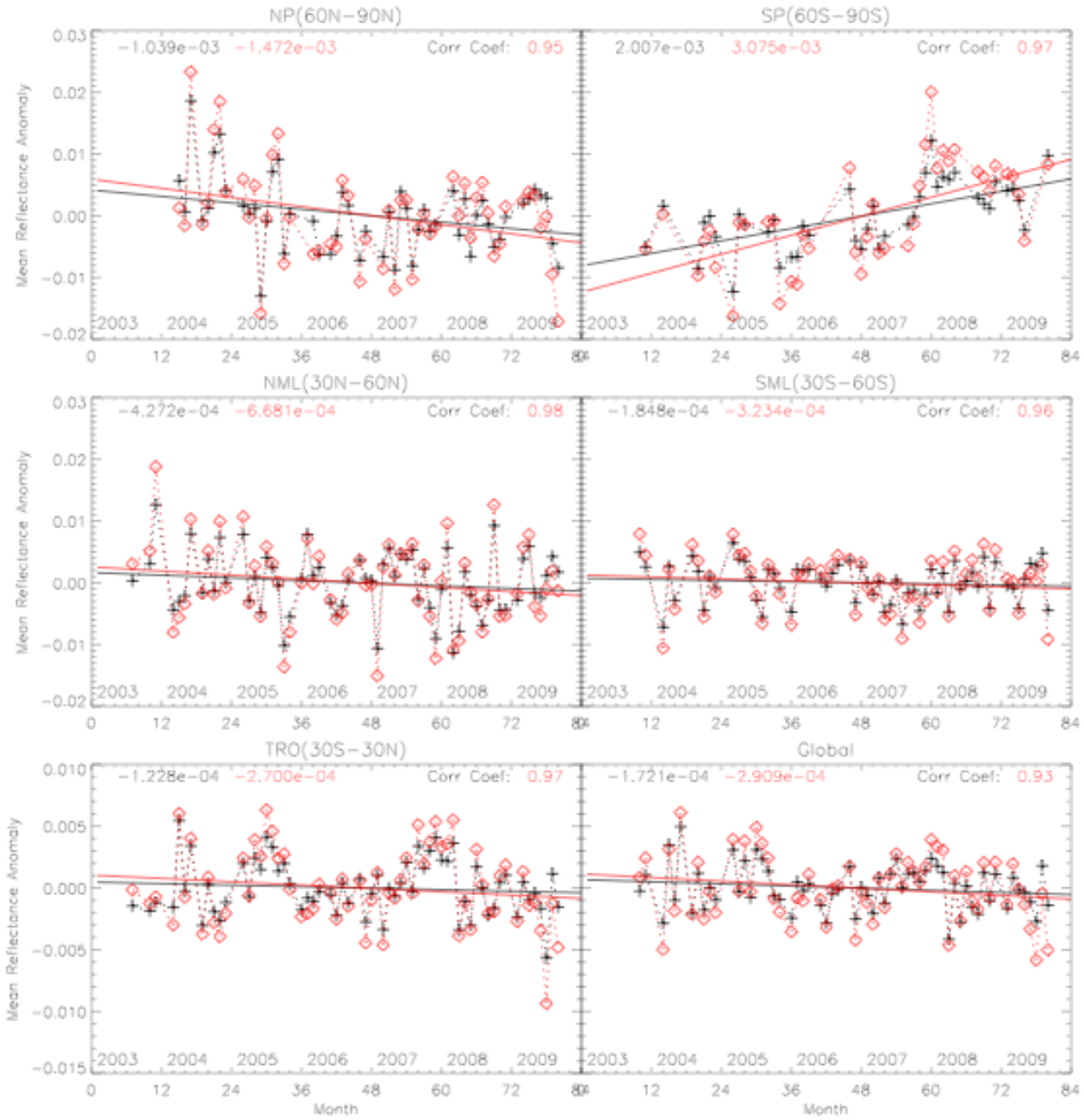
# Backup slides

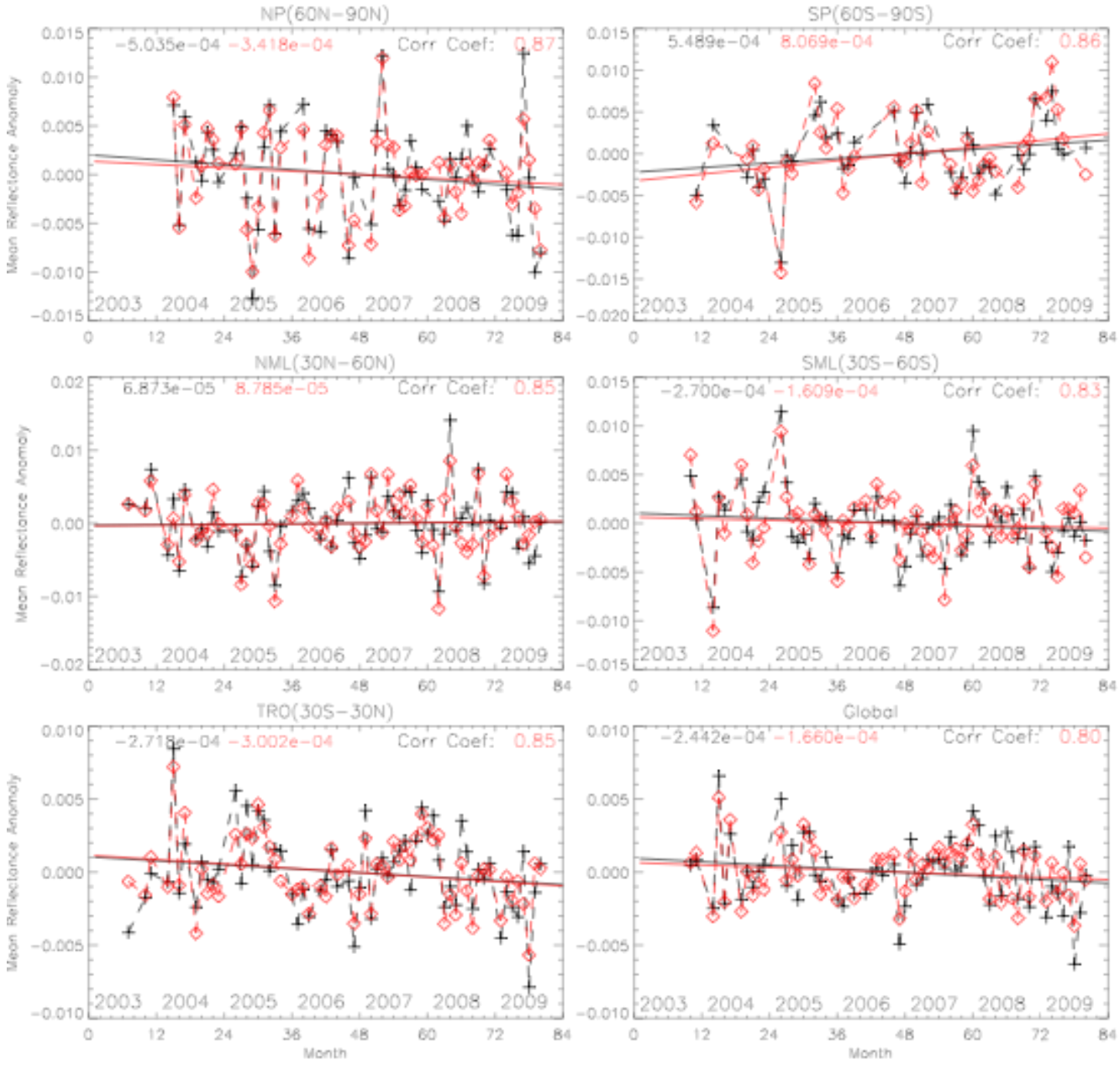
# SCIAMACHY Simulated Reflectance: MODIS Band 8




*Plot from Costy*


Month: 09
2004 2005 2006 2007 2008 2009
STD: 3.73(W/m2)
1.08978 1.09032 1.08859 1.08650
Month: 10
2004 2005 2006 2007 2008 2009
STD: 3.79(W/m2)
1.11068 1.10733 1.10682 1.10914
Month: 11
2004 2005 2006 2007 2008 2009
STD: 2.01(W/m2)
1.12320 1.12770 1.12481 1.12504
Month: 12
2004 2005 2006 2007 2008 2009
STD: 4.80(W/m2)
1.12965 1.13906 1.13827 1.13953
Solar Irradiance
Wavelength (micron)
0.0
0.5
1.0
1.5
2.0
2.5
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8


NP(60N-90N)
-1.039e-03 -1.472e-03 Corr Coef: 0.95
SP(60S-90S)
2.007e-03 3.075e-03 Corr Coef: 0.97
NML(30N-60N)
-4.272e-04 -6.681e-04 Corr Coef: 0.98
SML(30S-60S)
-1.848e-04 -3.234e-04 Corr Coef: 0.96
TRO(30S-30N)
-1.228e-04 -2.700e-04 Corr Coef: 0.97
Global
-1.721e-04 -2.909e-04 Corr Coef: 0.93
Mean Reflectance Anomaly
Month
2003 2004 2005 2006 2007 2008 2009
MODIS Chn 1 (640 nm)
CERES Ref (nadir)


NP(60N-90N)
-5.035e-04 -3.418e-04 Corr Coef: 0.87
SP(60S-90S)
5.489e-04 8.069e-04 Corr Coef: 0.86
NML(30N-60N)
6.873e-05 8.785e-05 Corr Coef: 0.85
SML(30S-60S)
-2.700e-04 -1.609e-04 Corr Coef: 0.83
TRO(30S-30N)
-2.718e-04 -3.002e-04 Corr Coef: 0.85
Global
-2.442e-04 -1.660e-04 Corr Coef: 0.80
2003 2004 2005 2006 2007 2008 2009
Mean Reflectance Anomaly
Month
SCIAM-MOD6
MODIS Ch6(1640nm)